Patient Positioning System for Radiotherapy/Radiosurgery Based on Magnetically Tracking an Implant

RELATED APPLICATION DATA

This application claims priority of U.S. Provisional Application No. 60/464,247, filed on April 21,2003, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to a method and a system for exactly positioning a patient in radiotherapy and/or radiosurgery and/or for taking into account shifts in internal structures of the patient caused by breathing, both during the actual treatment and while recording the image data necessary for said treatment.

BACKGROUND OF THE INVENTION

In radiotherapy and radiosurgery, major progress has been achieved in recent times in dosage planning. The aim is to use higher radiation doses that are applied to a target volume, for example, a tumor, as precisely as possible, without damaging the surrounding regions. Although dosage planning has been shown to be relatively successful, the use of higher doses, which in certain cases are even administered in a single or in a few fractions, is hindered by the fact that the patient or the section of the body to be treated can only be positioned relatively imprecisely. In order to avoid major damage to healthy tissue, exact positioning is essential.

Even optimally positioning the patient can, in certain cases, be insufficient, if the target tissue, which is to be irradiated, moves within the patient. Breathing movement can result in a shift of up to about 2cm. In order to be able to ensure optimal treatment even in these cases, it is necessary to know the exact position of the target area within the patient at any time during the treatment. If this position is known, then it is possible to activate the therapy device only when the target volume in the patient is within a range of tolerance about the target area of

the therapy device or, if it can be stipulated in the design of the machine in question, to slave the target area of the therapy machine to the movement of the target.

A related problem arises when recording the diagnostic images on which the treatments are based. If the interior of the patient moves while the image data is being recorded, then artifacts result in the images and the geometrical proportions of the interior of the patient are distorted. Correspondingly, the target volume within the patient is not detected in its true size, but may be shown too large or too small.

Furthermore, established x-ray-based methods generally only detect the osseous structures of the patient and are thus relatively unsuitable for treating organs that can shift relative to these osseous structures (for example, the prostate). A further disadvantage of x-ray-based methods is their limited resolution in time, and the resultant radiation load, when tracking shifts caused by breathing over a long period of time. The cost of stereoscopic x-ray systems is an obstacle for many applications.

SUMMARY OF THE INVENTION

The present invention may include any of the features cited in the claims and in this description, individually or in any combination.

In accordance with one aspect of the invention, the invention is directed to a method for positioning a patient or detecting a target volume in radiotherapy or radiosurgery. The method can include positionally referencing at least one implant in the vicinity of the target volume and inductively stimulating the at least one implant. Emission from the at least one inductively stimulated implant is detected and a position of the at least one implant is determined based on the detected emission. The current position of the target volume is determined based on the determined position of the at least one implant.

In accordance with another aspect of the invention, the invention is directed to a method for recording diagnostic, two-dimensional or three-dimensional image data sets in accordance with breathing. The method can include introducing at least one implant into the patient in the vicinity of the

target volume and inductively stimulating the at least one implant. Emission from the at least one inductively stimulated implant is detected and a position of the at least one implant is determined based on the detected emission. Image data is recorded based on the position of the at least one implant.

BRIEF DESCRIPTION OF THE DRAWINGS

These and further features of the present invention will be apparent with reference to the following description and drawings, wherein:

FIG. 1 is a flow chart illustrating a method of positioning a patient or detecting a target volume in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the detailed description that follows, corresponding components have been given the same reference numerals regardless of whether they are shown in different embodiments of the present invention. To illustrate the present invention in a clear and concise manner, the drawings may not necessarily be to scale and certain features may be shown in somewhat schematic form.

In one embodiment, the present invention employs one or more implants whose position can be determined via a magnetic tracking system. The implants are supplied with energy, for example, by inductively transferring electromagnetic energy via a dynamic field, which is beamed into the patient from without. In this way, cabling for the implant and an energy storage device in the implant can be omitted. It is to be appreciated that omitting external cabling significantly reduces the risk of infection for the patient.

With reference to FIG. 1, a method for positioning a patient or detecting a target volume is illustrated. The method can include introducing and positionally referencing 10 at least one implant in the vicinity of the target volume and inductively stimulating 20 the at least one implant. Emission from the at least one inductively stimulated implant can be detected 30 and a position of the at least one implant can be determined 40 based on the detected emission. The current position of the target volume can be determined 50 based on the determined position of the at least one implant. While the present invention is being

discussed in the context of radiotherapy and/or radiosurgery applications, it is to be appreciated that the present invention is amenable to other applications.

<u>Magnet tracking, using implants for positioning, on the treatment device</u>

The electromagnetic energy absorbed can be at least partially re-emitted by the implant, preferably in the form of an alternating field. If the signal emitted by the implant is measured in the vicinity of the patient, then the position of the implant relative to the measuring device or devices can be determined. It is to be appreciated that the position of the emitter is determined using a magnetic tracking system in a suitable manner.

If the position of the measuring points (i.e., the position of the points at which the emitted electromagnetic radiation is detected or measured), relative to the therapy device is known, then the position of the implant relative to the therapy device can therefore also be determined.

In accordance with one exemplary embodiment, the invention will now be illustrated using the example of a conventional linear accelerator whose gantry can rotate about a horizontal axis. However, it is to be appreciated that the present invention can equally be used with linear accelerators that are guided on robot arms having a number of degrees of freedom or also with therapy systems based on radioactive decay.

The position of the measuring points relative to the therapy device can be known either from their fixed connection to the therapy device or can be determined in real time via a six-dimensional tracking system (3 translatory and 3 rotatory degrees of freedom). In one embodiment, the ExacTrac™ system of BrainLAB AG may be employed as an example of a system capable of tracking the position of a measuring head, fitted with one or more sensors, in six dimensions. This second solution has the advantage that the sensors for measuring can be arranged very near to the patient, and then removed again after measuring. The nearer to the emitter the measurement is taken, the less output is required by the emitting implant and the less effect any interference fields have.

Magnetic tracking, using implants for treatment triggered by breathing, on the treatment device

If the position of the implant can be determined several times a second, then any shift of the implant caused by breathing and, therefore, any shift of the target volume within the patient, can be determined. Knowledge of the position of the implant can be used during the treatment to activate the therapy device when the position of the target volume in the patient is within a predetermined range of tolerance about the current target point of the therapy device. Alternatively, the therapy device or the patient can also be shifted according to the movement of the target volume.

In cases in which there is a negative interaction between the therapy device and the magnetic tracking system, the same function can also be indirectly achieved by linking it to another tracking device (for example, ExacTrac™ of the firm BrainLAB AG, Kirchheim/Heimstetten). In addition, at the same time as the measurement is taken magnetically, a physiological change in the patient is measured, for example, the movement of the thorax and the stomach wall during breathing. By correlating these two signals, it is possible, even at a late stage, to control the subsequent irradiation exclusively on the basis of the signal from the second tracking system.

Magnetic tracking, using implants for recording diagnostic images, triggered by breathing

Recording the diagnostic images on which the treatments are based can be solved similarly. In order to avoid artifacts in the images and distortion of the geometrical proportions in the data sets, it is necessary for all the image data to match one lung filling of the patient as exactly as possible. If all the tomographic images are taken at times when the patient has the same lung filling, then it is ensured that each point in the patient's interior is only imaged in exactly one tomographic image. In order to achieve this, the position of the implant can be continuously tracked on the imaging device (e.g., CT), and recording a tomographic image is only started when the position of the implant in the patient

is within a predetermined range of tolerance about a previously established position.

Magnetic tracking, using implants for preparing for positioning, outside the treatment position

Interference fields, and metallic and other electrically conducting objects, which distort magnetic fields, are critical for magnetic tracking. If, despite all measures, it is not possible to measure to a sufficient accuracy in the vicinity of the therapy machine, then the present invention provides an alternative embodiment.

By combining the magnetic tracking system with another, e.g. optical, 3D tracking system that can spatially determine the position of the measuring points, it is possible to measure the position of the implant in a space or in a region of a space in which there are fewer sources of interference. A possible implementation of this approach will now be explained by way of the ExacTrac™ system of BrainLAB AG (Kirchheim/Heimstetten). In this embodiment, the electromagnetic measuring points are in a known, preferably fixed, spatial relation to reference points that are detected by the tracking system. Such tracking systems include those disclosed in commonly owned U.S. Patent No. 6,351,659, which is incorporated herein by reference in its entirety. In this embodiment, reflective spheres are situated on a solid structure, which is fixedly attached to the patient or to the couch on which the patient is lying. The position of the implant relative to the measuring points can then be determined and the position of the implant relative to the reflecting spheres can be determined using the known spatial relation between the reflecting spheres and said measuring points.

If the patient is then moved to the therapy device, this spatial relationship should not changed. This can be realized by moving the patient, together with the couch on which he is laid, to the therapy device. Additionally, the patient can also be fixed to said couch.

When the patient is lying on the patient table of the therapy machine, the position of the reflective spheres is detected in real time. Since the spatial

relationships between the implant and the target volume in the patient and between the implant and the reflective spheres are known, the patient can then be positioned on the basis of the reflective spheres such that the target volume in the patient is positioned correctly relative to the therapy machine.

Magnetic tracking, using implants for preparing for treatment triggered by breathing, outside the treatment position

In another embodiment, it may be desirable in treatments triggered by breathing to take the magnetic measurements away from the therapy machine. In addition to the advantage that interference fields and signals can be avoided, this can reduce the time that the patient spends on the therapy machine. As already described further above, a physiological change in the patient is additionally measured, for example, the movement of the thorax and the stomach wall during breathing, at the same time as the measurement is taken magnetically. By correlating these two signals, it is possible to establish a criterion for the independent system that ensures that the implant is situated in the correct position in the patient.

If the patient is subsequently moved to the therapy device, then he can be irradiated exclusively on the basis of the signal from the second tracking system, which likewise has to be present on the therapy device.

Although particular embodiments of the invention have been described in detail, it is understood that the invention is not limited correspondingly in scope, but includes all changes, modifications and equivalents coming within the spirit and terms of the claims appended hereto.